COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 10

GEOLOGICAL RECONNAISSANCE OF SOUTH-WESTERN PORTION OF NORTHERN TERRITORY

Copy 1

By

G. F. JOKLIK

ISSUED UNDER THE AUTHORITY OF SENATOR THE HON. W.H. SPOONER,

MINISTER FOR NATIONAL DEVELOPMENT

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LIST OF REPORTS

1. Preliminary Report on the Geophysical Survey of the Collie Coal Basin - N. G. Chamberlain, 1948.

2. Observations on the Stratigraphy and Palaeontology of Devonian, Western Portion of Kimberley Division, Western Australia - Curt Teichert, 1949.

3. Preliminary Report on Geology and Coal Resources of Oaklands - Coorabin Coalfield, New South Wales - E. K. Sturmfels, 1950.

4. Geology of the Nerrima Dome, Kimberley Division, Western Australia - D. J. Guppy, J. O. Cuthbert and A. W. Lindner, 1950.

5. Observations of Terrestrial Magnetism at Heard, Kerguelen and Macquarie Islands, 1947 - 1948. (Carried out in co-operation with the Australian National Research Expedition, 1947 - 1948) - N. G. Chamberlain, 1952.

6. Geology of New Occidental, New Cobar and Chesney Mines, Cobar, New South Wales - C. J. Sullivan, 1951.

7. Mount Chalmers Copper and Gold Mine, Queensland - N. H. Fisher and H. B. Owen, 1952.

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   Part 1. Geological - H. B. Owen and G. M. Burton.
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1. SUMMARY

Early in the present century a prospector named L.H.B. Lasseter claimed to have discovered a rich gold reef near the West Australia-Northern Territory border. He perished in 1930 in an attempt to relocate his find. Several expeditions have been organized since then with the object of rediscovering it. By arrangement with the Director of Mines, Northern Territory, the writer accompanied a privately financed expedition in the summer of 1950-51 in order to obtain as much geological information as possible about a relatively little-known part of the Northern Territory.

Some data were obtained on the regional stratigraphy and geological structure of "Lasseter's Country" and the area east of it. The boundaries between rocks considered to be of Archaeozoic, Proterozoic and late Palaeozoic age, which occur between Alice Springs and the West Australian border, were outlined.

The MacDonnell Ranges and the Petermann Ranges, which are approximately 300 miles apart, are composed of rocks of Pre-Cambrian age. Between them lies a physiographic and structural depression which contains Lake Amadeus, and in which rocks of Lower Palaeozoic age crop out. Parallel to the margins of this depression strike-faulting has produced repetition of the Proterozoic and possibly of the Lower Palaeozoic sediments. The writer does not agree with the concept of a "structural sunkland" on the site of the present Lake Amadeus depression as postulated by Chewings (1931).

The party failed to discover any gold. Numerous quartz veins were found in the crystalline Archaeozoic rocks. The rocks of younger age were concluded to be barren of any payable mineralization.

2. INTRODUCTION

A concise account of the alleged original discovery of Lasseter's Reef and of the subsequent attempts to relocate the reef is given by Ellis (1936, pages 74-76).

> "Early in the twentieth century Lasseter lost his bearings in the MacDonnell Ranges to the west of Alice Springs whilst travelling in that country with horses. In his wanderings alone he found this fabulously rich gold reef, and was only saved from perishing by an Afghan who found him, to be ultimately restored to health by a surveyor named Harding. Several years later he set out with Harding and again found their watches to be an hour and a quarter slow, hence the calculated position of the reef was 100 miles out as a consequence. (Actually about 1,100 miles).

> In 1929 or 1930, as a result of personal representations made by Lasseter to residents of Sydney, the Central Australian Exploration Co., Ltd., despatched a well-equipped party with Lasseter as guide to locate this reef. The result of this exploration was that Lasseter again found the reef when by himself, but perished in the Petermann Ranges".

Subsequent expeditions to the alleged locality of Lasseter's Reef were led by M. Terry in 1930, Blatchford and Talbot, in 1931, by R. Buck (financed by V. Foy) in 1936; also, in 1931, D. McKay surveyed some portions of the Northern Territory, including the Petermann Ranges.

Since 1936 other parties have left both Alice Springs and Laverton, Western Australia, for "Lasseter's Country".

About some of these expeditions Ellis states:-

> "In recent years several claims to the discovery of Lasseter's Lost Reef have been made; in each instance, as in Lasseter's own case, the Reef has been seen by only the alleged discoverer. Strangely enough too, when nearing the supposed locality of the Reef the finder generally either quarrels with his mate, or for some other reason goes away by himself and returns with the statement that he has found the Reef, but never yet has anyone produced any specimens which unquestionably came from the Reef".

In January and February 1951, an expedition organized and financed by the Sydney company Centralian Holdings Limited, and by some private individuals, undertook the journey from Alice Springs to the country of Lasseter's original claim. Some members of the party claimed to have previous information concerning the location of gold in that area, and one prospector stated that he had discovered a very rich gold reef near the Petermann Ranges in 1946.

At the suggestion of the Director of Mines, Northern Territory, the Bureau of Mineral Resources arranged that the writer should accompany the party as geologist and attempt to gain as much geological information as possible about the area to be examined. No previous geological report had been made on the country along the route to be traversed between Alice Springs and "Lasseter's Country", except for the section between Piltardie Rock Hole, approximate Latitude 25° 04'S., and Longitude 129° 49'E., and Livingstone Pass, approximate Latitude 24° 49'S., and Longitude 129° 14'E. Previous geological work in Central Australia with any bearing on the description to follow is contained in the writings of Ward (1925), Madigan (1931, 1932), Chewings (1931, 1935), and Voisey (1938).

Very little accurate topographic detail is shown on existing maps. Plate 1,Geological Sketch Plan of the Western Portion of Central Australia, embodies extensive modifications of, and additions to, the appropriate Australian Aeronautical Sheets at a scale of 1:1,000,000. Plate 2,Geological Sketch Map of the Petermann Range - Rawlinson Range area, is compiled chiefly from the writer's own observations. During the expedition, the available Australian Aeronautical Sheets, Military Maps, and the maps included in the report by Ellis (1936) were used.

No minerals of economic importance were discovered in the course of the expedition which, from the point of view of the organizers, was a failure. The writer, on the other hand, turned his attention to mapping on a large scale a section of the Northern Territory in which very little geological investigation had previously been carried out. . This therefore is not a report on the economic geology but an account of all geological observations made on the trip.

3. ITINERARY

From Alice Springs the expedition followed the graded road to Ayers Rock; the party then travelled west as far as the eastern end of the Petermann Ranges. A track made between the ranges by a previous expedition led to Livingstone Pass, through which the bed of the Docker River passes. From the Pass, two traverses were undertaken, one north-west, the other west, into West Australian territory. The same course was followed on the return journey to Alice Springs (Plate 1).

The expedition, which was equipped with three four-wheel drive vehicles, followed the overland track to Adelaide from Alice Springs as far as four miles south of the Finke River crossing. A graded track connects this point with Curtain Springs Station, the most westerly cattle grazing area. The distance between Curtain Springs Homestead and Alice Springs is 206 miles. Two-wheel drive vehicles are likely to be held up by the Finke River in the wet season, and by the Palmer River in the "dry". The road passes alternately through good grass country and patches of spinifex.

Between Curtain Springs and Ayers Rock numerous sand-ridges striking east-north-east make progress difficult. Although the distance by air is only 40 miles, the road winds tnrough shallow valleys and over miniature passes for about 67 miles. Ayers Rock lies within the boundary of a large aboriginal reserve that extends to and beyond the West Australian border; until the expedition returned to Ayers Rock, the route followed lay entirely within the reserve.

West of Ayers Rock, no roads or tracks exist. Eighteen miles by car north-north-west of Ayers Rock, near the centre of a group of bare ridges, is situated the base camp of an exploration company that once held a mining reservation in this area. The ridges are composed of apparently barren quartzite.

From the mining reservation a westerly course was taken between Mount Currie and Mount Olga, two isolated groups of giant boulders in the spinifex desert. A few patches of mulga break the monotony of the desert. For twenty miles east of the Armstrong River Crossing, some particularly troublesome sand-hill country is crossed. The Armstrong has its source near Piltardie Rock Hole, a watering place that marks approximately the south-eastern end of the Petermann Ranges. The course followed by the expedition described a semi-circle around Piltardie, and skirted the most north-easterly foot-hills of the Petermann Ranges. The dry bed of the Irving River was crossed at approximate Latitude 24° 58'S. and Longitude 129° 46'E. Three parallel chains of hills, the southern most of which is the Petermann Range proper, extend north-west from the Shaw River, which was crossed seven miles west-south-west of the Irving.

Lasseter's Cave is in the gap between Mount Fagan and Mount Curdie; the Hull River flows through the gap. From there, the sandy valley between the main range and the chain of hills north-east of it was followed as far as the Ruined Ramparts Aerodrome, an emergency landing ground cleared by D. McKay in 1930. The route then swung west, parallel to a change in strike of the range.

Base camp was established in Livingstone Pass, at the eastern end of the Dean Range. The valley of the Docker River, which flows through the Pass, contains some excellent grass country; however, the valleys that separate the bare, hog-backed ranges support only spinifex and desert oak; numerous sand-ridges, particularly in the vicinity of gaps in the ranges, make progress difficult.

At Livingstone Pass a group of eight natives of the Pitjentara tribe was encountered; they had walked from Sladen Waters (Plate 2) to Livingstone Pass in reply to the expedition's smoke signals. They were the only natives seen during the journey. The group included men, women and children, all in fairly good physical condition. During the traverse west from Livingstone Pass "smokes" were observed from the direction of Sladen Waters, and also from the desert north of the Walter James Range. The country north of Livingstone Pass and south of Blood's Range is Pintahpee tribal ground, and the only visible signs from this tribe were their "smokes". The writer concludes that the aboriginal reserve in the north-west corner of the Northern Territory is very sparsely inhabitated, although numerous natives were seen at homesteads on its fringes.

From Livingstone Pass, two round trips were made, both almost entirely at the direction of a prospector (a member of the party) who claimed knowledge of the situation of "a rich gold reef". During the first traverse the party travelled west from the Pass (approximate Latitude 24° 47'S., Longitude 129° 14'E.) along the valley between the Kathleen Range and the range whose highest peak is Giles Pinnacle. At Longitude 129°E the West Australian border was crossed; after a further fourteen miles west, the general course was altered to north-west; the westernmost camp on this traverse was established at approximate Latitude 24° 37'S., and Longitude 128° 33'E., a short distance west of the centre of a large amphitheatre formed by a massive quartzite range; the course then continued around the northern limb of this range. The Rebecca River, which flows northward towards Lake Hopkins, was crossed at approximate Latitude 24° 45'S. and Longitude 128° 48'E.; the party then kept on the north side of the unbroken, parallel mountain chains as far as the Docker River, which was followed back to the Pass.

As no signs of any gold-bearing reef were discovered on the traverse just described, another was planned; this traverse was carried out by only a section of the party. A course was taken due west from the Pass for nearly fifty air-miles. Mount Buttfield, at the western end of the Dixon Range, could then be seen approximately fifteen miles north-west; the western end of the Rawlinson Range was visible, west-south-west about forty miles; this range strikes west-north-west at the east; it is separated from the Schwerin Hills by a gap in which Sladen Waters is situated. Still farther east, the Mural Crescent connects the Schwerin Hills with the Kathleen Range ; the latter forms a block between the Giles Pinnacle Range and the Dean Range, which strikes south-west.

From the westernmost point of the traverse, the northern flank of the Mural Crescent was followed east as far as the Rebecca River; flat mulga country, excellent for travelling compared with the spinifex-covered sand-plains, extends along the southern side of the ranges in this area. Low schist hills are the only eminences. Similar terrain extends east into the valley between the Dean and Kathleen Ranges and was traversed back to the Pass.

After the re-union of the two parties, the decision was reached that no further exploratory traverses could be undertaken; first, no traces of payable gold had been found; secondly, the permit granted for entry into the Aboriginal Reserve did not cover West Australian territory; and finally the vehicles were in poor condition. Accordingly the expedition returned to Alice Springs along the tracks of the outward journey.

4. CLIMATE, FAUNA AND FLORA, WATER SUPPLIES

Between Alice Springs and the Petermann Ranges, the annual rainfall generally ranges from 0 to 10 inches. The months during which this precious water is most likely to fall are December, January and February. It is for this reason that the expedition was undertaken during the summer, although temperatures would have been more bearable later in the year. The summer of 1950/1951 was exceptional, as eighteen inches had been recorded in the eastern portion of this area by mid-January. At the time of the expedition therefore, the country looked deceptively fertile; water-holes and soaks were well-stocked.

Game seen during the journey consisted of pigeons and wild turkeys, emus, kangaroos, dingoes, rabbits and "spinifex rats". The natives also hunt several varieties of lizards, goannas and snakes. Despite the aridity of the country, rabbits are rapidly over-running all areas that carry useful feed, and will no doubt in time reduce them to desert.

West of the neighbourhood of Alice Springs, spinifex desert and patches of mulga bush, broken here and there by good grass flats, extend to and beyond the West Australian border. Parakylia is plentiful over most of the area and thrives particularly in patches where the spinifex has been burnt. Desert oak and mulga constitute most of the trees; patches of mallee are common. West of the Docker River, the bloodwood gum is abundant; practically all water courses are lined by white-barked river gums; in many places ti-tree indicates water close to the surface. Quandong trees, wild figs, desert poplars, kurrajong and beef-wood trees are other varieties noted.

Exact knowledge of the watering places is indispensable in the desert area of Central Australia. Between Ayers Rock and the Shaw River Crossing, a 110-mile dry stage in sandy country has to be negotiated. The Hull River near Lasseter's Cave, and the Docker River at Livingstone Pass, both contain good soaks. Two miles south of the Ruined Ramparts are some rock-holes which held plenty of water late in January. The expedition drew good water from a soak on the southern side of the northern limb of the Amphitheatre Range, and an excellent series of rock-holes was discovered in a gully on its northern side. Hidden in a deep re-entrant in the range, this source consists of at least two pools, each approximately 600 feet square and more than fifteen feet deep. Continuous replenishment keeps the water perfectly clear.

5. PHYSIOGRAPHY

Between Alice Springs and the Petermann Ranges, the physiographic profile is very closely related to the geological section (Plate 1). The Alice Springs plains, and the flat country separating the individual chains in the Petermann Ranges, are practically at the same altitude, approximately 2,000 feet. Between these elevated areas is the Lake Amadeus depression, whose deepest part lies approximately 500 feet below the 2,000 feet level. The physiographic profile between Alice Springs and the Petermann Ranges is therefore symmetrical; this symmetry is emphasized by the drainage pattern and the morphology of the mountain ranges.

The first range south of Alice Springs is the MacDonnell Range, with its sharp scarps to the north and dip-slopes to the south.

Farther south, the change into gently-dipping Lower Palaeozoic beds coincides with a gentle drop in the general level of the country towards the Finke River. The fall continues towards Curtain Springs; on either side of the road, low, practically flat-topped isolated hills and ridges are visible. East of Curtain Springs some large salt-lakes, former extensions of Lake Amadeus, are by-passed; they are at the lowest level of the depression crossed by the road. The sand cover is thick in this area, and the sand-hills have been partly reconsolidated and are thickly covered by vegetation.

Mount Conner, which is visible south-west from Curtain Springs Homestead, rises 1,000 feet above plain level. Airphotos show that it is surrounded by concentric ridges with intervening valleys, to which the geological structure appears to correspond. The topmost 300 feet of Mount Conner consist of flat-lying quartzite with a vertical scarp on all sides.

Ayers Rock rises steeply out of the desert sands. The smooth outline, the rounded caverns and the exfoliate mode of weathering have in the past led many observers to classify the rock as granite. It is actually composed of arkose, a felspathic sandstone. Because of its remarkable form, many theories have been put forward to account for the origin of "The Rock". The writer considers it to be the erosion remnant of a folded bed.

The outline of Ayers' Rock is lozenge-shaped, the longer diagonal bearing east and the shorter bearing north; dimensions of the diagonals are two miles and one-and-one-quarter miles respectively. The north-east face, which is parallel to the strike of the bedding, is marked by vertical joints perpendicular to the strike; large caverns are visible high above the plain level. The north-west and south-east faces, both oblique to the strike, are broken by numerous deep re-entrants, some of which contain rock-pools and springs with excellent water. The summit of the mountain is approximately 1100 feet above plain level.

Mount Olga and Mount Currie are physiographically very similar to Ayers Rock. In the Mount Olga group, weathering along north and east joints has divided what was originally a single mountain mass into numerous blocks of various sizes. Air photos show that the joint pattern is broadly radial; the centre of the joint-system is several miles north of Mount Olga. The area covered by the Mount Olga residuals is approximately fifteen square miles. The general dip of the beds composing it is gently to the south.

The physiography of the Petermann Ranges, and of the ranges further west, is very similar to that of the MacDonnells. The pattern of steep scarps and opposing dip-slopes is repeated on a larger scale, but in the Petermann Ranges the dip-slopes face north; examples are the Dean Range, Mural Crescent and Giles Pinnacle. Gentle folding commonly produces variations in the general pattern. Repetition of beds by faulting is common; in some places up to half a dozen parallel ranges have been formed in this way, and in such circumstances orientation in the field is very difficult. Invariably, quartzite caps the "hog-backs".

The Archaeozoic outcrops on either side of Judy Creek, in the Pottoyu Hills south of the Ruined Ramparts, and in the mica schist terrain south-west of the Kathleen Range, are inconspicuous physiographically; they form low, rounded mounds.

The drainage between the latitudes of Alice Springs and Mount Culloch is controlled by the symmetrical physiographic pattern. The flow-off from the MacDonnell Ranges and mountain systems farther west is due south, and the drainage from the Petermann-Rawlinson Ranges is due north. The catchment area is the Lake Amadeus-Lake Hopkins depression.

A battery of altimeters was carried on the trip. The readings made it possible to prove the symmetry of the physiographic profile and showed up in an error in the Alice Springs Sheet of the Australian Aeronautical map, on which the lake bed of the Amadeus depression is marked at an elevation of 670 feet. Readings south of the lake bed on the salt pans near Curtain Springs Homestead show that 1670 feet is a more probable value.

6. GENERAL GEOLOGY

(a) Introduction. Between Alice Springs and the Pottoyu Hills, rocks considered to be of Archaeozoic, Proterozoic, and Lower Palaeozoic age crop out. The term "Proterozoic" as used in this paper corresponds to David's (1932) "Newer Proterozoic" or Nullagine. No sediments of "Older Proterozoic" age are exposed between Alice Springs and the West Australian border. The main characteristics assigned by the writer to the rocks of each era are shown in Table 1.

TABLE 1.

Main characteristics of Archaeozoic, Proterozoic and Lower Palaeozoic Rocks of the area

	Archaeozoic	Proterozoic	Lower Palaeozoic
Rock types	Gneiss and crystalline schist, metamorphic basic rock, quartzite	Quartzite, phyllite, schist, some limestone	Quartzite, slate, sandstone, limestone
Metamorphic Grade (Typical Facies)	Amphibolite Facies	Greenschist Facies	Slight regional metamorphism
Intrusions	Intruded by granite	Not intruded by granite; thin quartz stringers common	No intrusives
Folding	Tight	Moderate	Mostly sub-horizontal
Metamorphic Structures	Foliation and schistosity Regional lineation	Schistosity Regional lineation	Slaty cleavage No regional lineation
Fossil Content	No fossils	No fossils	Ordovician fauna described; Etheridge (1897) Tate (1896)

Several classifications of the sediments of Central Australia have been proposed. These differ chiefly because very little systematic work has been done, and each writer has recorded his personal impressions, gained mainly as the results of quick reconnaissance trips; inaccessibility of most of the country is a great obstacle to detailed work in these remote areas. The classification given above has suggested itself as the natural one after two years' work in the Harts Range-Alice Springs region and is not merely the result of knowledge gained on the present expedition. In the area under consideration, Ward (1925) recognized only Pre-Cambrian and Lower Palaeozoic rocks, the latter including all sediments marginal to the crystalline "shields"; some of these sediments contained an Ordovician fossil fauna. (The present writer also does not discount the possibility that the "Proterozoic" is merely a portion of the Lower Palaeozoic succession marginal to the crystalline basement).

Ward, as opposed to Madigan and Chewings, recognized the possibility that strike-faulting might have increased the apparent thickness of the post Pre-Cambrian sediments.

Madigan and Chewings divided the "Post Archaeozoic" rocks into "Lower Proterozoic" and "Upper Proterozoic", "Cambrian", and "Ordovician". They correlated the "Lower Proterozoic" quartzite, which is exposed at Heavitree Gap two miles south of Alice Springs, with the quartzites that, in the case of some mines, form the country-rock in the Arltunga, Winnecke, and White Range Goldfields. As some of the quartzites that crop out in the Goldfields appear to be an integral part of the "Archaeozoic" succession of schists and gneisses, they concluded that "the greatest revolution that has ever affected the MacDonnells" took place after the deposition of the Heavitree quartzite (Madigan, 1932, p.106). On the other hand, no evidence of an unconformity between quartzites that can safely be correlated with the Heavitree Quartzite, and the overlying "Cambrian" rocks, has been found anywhere in Central Australia. The explanation is that Madigan's and Chewings' correlation is not valid. The writer regards the schists and gneisses and the quartzite bands in the Arltunga Goldfield as Archaeozoic. They are separated by an unconformity from the Lower Proterozoic White Range Quartzite which again is unconformable with the Upper Proterozoic Heavitree Quartzite.

On Plate 1 is shown the areal distribution of the rocks considered to be of Archaeozoic, Proterozoic and Lower Palaeozoic age.

(b) Archaeozoic. The Archaeozoic crystalline rocks form the country north of the Heavitree Range, near Alice Springs, and they also appear between the strike-faulted Proterozoic quartzite ranges south of the Heavitree Range. Garnet-mica schists and acid gneisses, intruded by numerous pegmatite veins, predominate. Madigan (1932) applied the name Arunta Complex to these rocks and referred to the crystalline mass as a shield.

In the course of the expedition no further Archaeozoic sediments were traversed until the Armstrong River had been crossed at approximate Latitude 25°9'S., Longitude 130°06'E. About five miles west-north-west of this point is a group of hills in which steeply dipping quartz-mica schist underlies sub-horizontal quartz conglomerate and quartzite. The underlying rock shows schistosity and lineation, and alternating light and dark segregations.

One mile east of Judy Creek (Plate 2) the expedition's route crossed some smooth low outcrops of a coarse garnet-biotite-epidote gneiss containing quartz and felspar augen. Some very similar rock types from the Harts Ranges have been examined by the writer. In the bed of Judy Creek a pegmatized acid gneiss, intruded by discordant pegmatite veins, crops out; it is associated with lineated amphibolite consisting of hornblende, biotite and oligoclase-felspar; quartz, apatite and magnetite are accessories. Nearer the Irving River more varieties of mica gneiss and schist crop out.

The Pottoyu Hills, which are composed of gneiss and granite, represent the northernmost unbroken extension of a second great area of Archaeozoic rocks, the Pitjentara Shield. The Musgrave Ranges are the south-western continuation of this basement area, which is the counterpart of the Arunta Complex to the north.

South-west of the Kathleen Range, are lineated crystalline quartz-mica schist and sheared granite-porphyry containing many quartz veins and probably of Archaeozoic age.

(c) Proterozoic. South of Alice Springs, in the Heavitree Range, "Proterozoic" rocks, equivalent to the "Pertaknurra Series", (Madigan, 1931), overlie the Archaeozoic (Arunta Complex) basement rocks with a strong angular unconformity. Similar beds overlie the older Pre-Cambrian occurrences described above, for example, the strike-faulted ridges of the Petermann Range area.

As differential weathering produces physiographic differences between the formations on either side, no difficulty was experienced in delineating the Archaeozoic - Proterozoic boundary south of the Petermann Range. At Livingstone Pass a section through the

Proterozoic succession is exposed. The topmost member is a thick bed of quartzite, protecting the dip-slope which faces north; it forms the top 200 feet of the scarp which faces south. The rock is massive, white, and fine-grained and shows marked lineation. In thin section, quartz and sericite are seen to form a cement between strained quartz grains of average diameter 0.75 mm. Ferromagnesian minerals are practically absent.

Lower in the section, quartzite bands become thinner and fewer; most of the rock consists of various types of schist, stained red by iron oxides. One band contains quartz pebbles of 3 mm. average diameter in a soft sericite-limonite base. Another type of schist is composed of sheared angular fragments of slate and quartzite in a streaky pinkish-grey matrix which contains nearly 90 per cent sericite. Near the Ruined Ramparts was found a low-grade sheared felspathic schist which, in thin section, is seen to consist mainly of quartz, myrmekite, micropegmatite, and saussuritized plagioclase, and finely divided aggregates of sericite, biotite, epidote, hematite and chlorite.

In some metamorphosed breccias, shearing has produced a texture which is more commonly due to metamorphic differentiation; the light and dark fragments have been drawn out into alternating bands.

The Proterozoic rocks were apparently metamorphosed by movement under pressure rather than by re-crystallization at depth. The minerals they contain belong to a stress assemblage which is typical of the greenschist facies.

(d) Lower Palaeozoic. The area between the MacDonnell Ranges and the Petermann Range - Olia Chain system is occupied mainly by flat-topped ridges composed of flat-bedded sandstone, slate, quartzite, and limestone beds; these rocks dip more steeply against the mountain chains that hem them in to north and south. Fossils of Ordovician age have been described by Etheridge (1897) from the James Range (from collection by H.Y.L. Brown), and by Tate (1896) from the Horn Valley (from collection by the Horn Expedition).

Five miles east of the turn-off to Angus Downs Homestead, (Plate 1), a white sandstone was collected. The rock is fine-grained, very friable, and contains quartz grains of 1 mm. average diameter. No directional structure is apparent, nor is there any trace of the effects of dynamo-metamorphism or recrystallization. Plate 1 shows that the locality in question is mid-way between the northern and southern Proterozoic boundaries, and the degree of metamorphism there is less than in any other area between Alice Springs and the Petermann

Ranges. A metamorphic gradient exists within the Lower Palaeozoic succession from the centre of the Lake Amadeus depression outwards. The writer ascribes this, not to any age differences between the metamorphic varieties, but to the localization of thrust movements along the edges of the depression. This concept could be extended to include the "Proterozoic" sediments, but at present the writer considers it more advisable to retain a division based on such criteria as are listed in Table 1.

The Ayers Rock-Mount Olga-Mount Currie line of residuals is close to the southern limit of Lower Palaeozoic outcrops. In particular, the rock that comprises Ayers Rock is structurally similar to the more strongly folded Proterozoic beds. The rock is a coarse arkose, which shows no secondary directional structures. In thin section fairly rounded grains of quartz and felspar (mainly microcline and plagioclase) are seen to be cemented by a soft matrix. Various ages have been assigned to the Ayers Rock-Mount Olga line, including Pre-Cambrian (Ward, 1925), Devonian (Chewings, 1931) and Proterozoic (Chewings, 1935). Correlation with the Lower Palaeozoic sediments appears to be the most logical conclusion.

Approximately thirty miles east of the Armstrong River, the expedition's route crossed patches of rock detritus consisting chiefly of pebbles of various types of igneous rocks; these included aplite, granophyre, rhyolite and porphyrite.

This assemblage is probably related to the Lower Palaeozoic-Proterozoic boundary, and, because of the absence of any stress-effects, is included at the base of the Lower Palaeozoic succession.

7. STRUCTURE

(a) Archaeozoic. Complex folding, faulting and migmatization characterise the rocks that make up the Arunta Complex and the Pitjentara Shield. Schistosity is prominent in the finer-grained micaceous rocks; the gneissic texture of the coarser-grained varieties is emphasized by foliation. In detail, small nappe structures overthrusting and over-folding can be seen; the copious injection of acid magmatic fractions suggests that at some time these rocks possessed great mobility. Lineation - plunging in roughly the same direction (to the north-north-east) wherever measured - gives the impression that the deforming forces that accompanied the metamorphism of these rocks acted uniformly over a large area.

Metamorphosed sedimentary formations can be mapped in the Archaeozoic by tracing their boundaries, and the structure can be solved by mapping foliation and schistosity planes. Fold structures in the Archaeozoic can be divided into three orders of magnitude; first, regional folds such as the Harts Range Anticline, secondly, folds of much more limited dimensions such as occur in individual members of formations, and thirdly, the small-scale folding seen in fresh exposures of apparently unfolded single beds.

These third order folds are folds of the bedding of the rocks which were metamorphosed to schists and gneisses. They are generally tight and practically isoclinal. Hence the axial planes of the third order folds approximate to the original bedding planes. In many instances it has been found in the field that the axial planes of the third order folds lie parallel to the planar secondary structures which are mapped as "bedding" in the second and first order folds; it follows that these secondary structures, which are conspicuous on air photos, represent at least approximately the true bedding of the rocks.

Next to schistosity and foliation, lineation is the most prominent structural feature in the crystalline rocks. Readings of the direction of plunge of lineation ranging in azimuth from 10 degrees west to 5 degrees east of magnetic north were recorded in the Judy Creek area, the Pottoyu Hills, and the Mural Crescent occurrences; plunges were as a rule below 20 degrees. This direction accords well with numerous bearings recorded in the Harts Range area, and with some readings taken in the vicinity of Alice Springs. It is in general at right angles to the regional strike of the Archaeozoic rocks and parallel to the direction of over-thrusting.

(b) Proterozoic. A marked angular unconformity separates the Archaeozoic from the Proterozoic rocks. Five miles west-north-west of the Armstrong River Crossing, the angle of unconformity was measured at 50°, although generally this value varies a good deal because of the tight folding of the Archaeozoic beds.

Structures in the Proterozoic rocks suggest that movement has played an important part in their metamorphism. The quartzites, metamorphic breccias and schists are sheared and lineated. The breccias appear to be at least in part fault breccias, and not entirely metamorphosed sedimentary breccias. Assemblages of stress minerals were described on page 19.

The Proterozoic beds have not been intensely folded. Open folds such as the Amphitheatre Range structure are the general rule, but some overturning of folds has taken place. At Livingstone Pass, the writer observed miniature overthrusts and overturned folds that suggest a comparison with major structures. Plates 1 and 2 show how pressure from the marginal massifs of the post-Archaeozoic basin has caused multiple repetition of some Proterozoic beds.

Although small-scale over-folding does occur in some places in the Petermann Ranges, this does not apply to the parallel "hog-backed" ranges (e.g. the Mount Fagan-Mount Curdie Range) which closely resembles the ridges south of Alice Springs. As far as could be ascertained, the stratigraphical succession is never reversed. On the other hand ample evidence of movement has already been given; the metamorphic breccia beds, which increase in number and thickness towards the base of each "thrust-flake", and the identical character of the individual flakes support the concept of repetition by thrusting. Unless repetition either by thrusting or by overturned isoclinal folds is admitted, a thickness of approximately 45,000 feet of sediments must be allotted to the Proterozoic at the eastern end of the Petermann Ranges.

(c) Lower Palaeozoic. No angular unconformity has been discovered between rocks supposed to be of Proterozoic and those supposed to be of Lower Palaeozoic age either south of the MacDonnell Ranges or north of the Petermann Ranges.

The attitude of the Lower Palaeozoic strata is commonly sub-horizontal, but along their northern and southern boundaries they dip north and south respectively in conformity with the underlying Proterozoic beds. No secondary metamorphic structures other than slaty cleavage have been developed in them.

Near Alice Springs, immediately south of the ranges consisting of Proterozoic quartzite, the Lower Palaeozoic quartzites, slates and limestones dip south at 35° to 45°. The sandstones between the Palmer River and Curtain Springs Station are flat-lying. The quartzites near the Reservation Camp dip south-west at approximately 20°. The sediments of which Ayers Rock is composed strike north-west; the dominant direction of dip there is to the south, but the Rock contains several anticlines and synclines. The maximum angle of dip of the bedding is approximately 55°, although Chewings (1931) regarded the strata as lying "near the horizontal". The re-entrant at Maggie's Springs exposes an anticline plunging north-west, and similar folds occur elsewhere in this massive rock outcrop.

The beds comprising Mount Olga dip south-west at approximately 20°. Other Lower Palaeozoic outcrops, even closer to the Proterozoic boundary, for example the rocks of Blood's Range, dip north in conformity with the underlying sheared schists and quartzites.

(d) Regional. The Archaeozoic rocks appear to be a continuation of the Lower Pre-Cambrian of West Australia. The general strike, from west of the West Australian border across to the Jervois Range and beyond, is east. In the geological sketch section across the Petermann and MacDonnell Ranges (Plate 1), the structure between the Arunta Shield and the Pitjentara Shield is shown. Two stable crystalline massifs enclose a conformable succession of younger sediments in a gentle basin.

Chewings (1935) brought forward a theory that a graben (the "Amadeus Sunkland"), bordered by normal faults of large displacement, existed on the site of the Lake Amadeus depression. According to him, it contained the post-Pertaknurra (i.e., post-Lower Proterozoic) sediments, and occupied the full width between the southern margin of the Arunta Complex and the northern margin of the Pitjentara Shield.

> "The concept of a sunkland in lieu of a down-warped valley between the Arunta and the Pitjentara Shields originated while delineating on the map the areas occupied by the different formations. They showed that the Larapinta Series was bordered by more or less straight lines in localities far removed from the great fault that runs east-west a little south of Alice Springs. The great disparity in age of the opposing formations on either side of the postulated faults, in the writer's opinion, justifies the definition, as also does the abysmal drop, and the more intense folding it underwent."

Describing the actual history of the events, Chewings wrote (p. 145):

> "At the close of the Pertaknurra (lower Proterozoic) peneplanation, nearly all Central and North-west Australia subsided beneath the ocean and, with possible sub-aerial intervals, remained there under quiescent conditions until the building up of the 12,000 feet or so of the sediments that comprise the new series (Upper Proterozoic or Ordovician) was complete. (The measurements are Madigan's). The elevation of all Central and North-west Australia ensued. The foundering of the sunkland during, or soon after, the elevation preserved that portion of the newer series largely intact, but the basal portion of the new series, viz., the Pertatataka (Upper Proterozoic) residues was removed from the more elevated parts of Central Australia outside the sunkland." Finally, (p.149):

> "The great rift appears to follow the southern quartzite limb of the Alice anticline throughout, which suggests that there may have been a line of weakness there - a relict of the Pertaknurra revolution."

Chewings then supports his theory by some calculations involving the estimated thickness of the post-Archaeozoic sediments and present-day differences in elevation.

In view of information collected during the present investigation, it is more probable that a gentle down-warp separates the two masses of schist and gneiss.

The idea of a "great rift" is not justified, as the sedimentary record proves that there was no great "Pertaknurra revolution". The "straight lines" noted in delineating the formations are deceptive; the natural regional strike is east, hence the boundaries also remain reasonably true to that direction.

The Lower Palaeozoic - Proterozoic boundary north of the Petermann Ranges does not follow a straight line (Plate 1).

Chewings uses as an argument the "great disparity in age" of the opposing formations (i.e. Lower and Upper Proterozoic separated by the post-Lower-Proterozoic diastrophic epoch) on either side of the postulated faults. In the area in question, however, all Proterozoic rocks are probably of Upper Proterozoic age, and there is certainly no trace of an unconformity that could support a "great disparity in age". The consideration that finally made the concept of a great vertical displacement, aided by normal faulting, appear inevitable, was the great apparent thickness (12,000 feet according to Madigan (1931)) of post-revolution sediments which had to be fitted in. The apparent thickness in the Petermann Ranges is even more formidable. If the base of this succession is visible 20 miles north of Hermannsburg Mission Station (Chewings 1935) and the topmost remaining beds are exposed at the Mission Station, an "abysmal (stratigraphic) drop" of 12,000 or more feet has to be accounted for. If multiple repetition as postulated herein has greatly increased the apparent thickness, no great subsidence of the crystalline basement has to be supposed.

8. TECTONIC HISTORY

The close of Archaeozoic sedimentation was followed by a diastrophic epoch, probably the last of many, which obliterated the structural results of the preceding revolutions and which was accompanied by migmatization, granitization, and granitic, pegmatitic and basic injections. Whilst some of these processes were continuing, severe folding increased the degree of metamorphism of the complex. Uplift preceded a long period of erosion.

Sea invasions succeeded; Proterozoic sedimentation was extensive, and at its conclusion there was probably a slight pause accompanied by gentle warping. Differential movement took place between the freshly consolidated sediments and the margins of the east-west depression in which they had been deposited. The Archaeozoic complex had by this time taken the form of two stable anticlinal blocks, the Arunta and Pitjentara Shields, and a slowly subsiding basin, the Amadeus depression.

Before sedimentation continued early in the Palaeozoic era, igneous intrusions and volcanic activity occurred in some areas, and were accompanied by slight epeirogenic movements. The last conclusive evidence of marine sedimentation in the Alice Springs area is found in the fossiliferous Ordovician beds 80 miles west of Alice Springs. When finally the seas did retreat, probably at the close of the Ordovician, a north-south compressive couple caused movement and repetition of beds marginal to the borders of the Archaeozoic shields.

After the close of the Mesozoic, at some time during the Tertiary, a general uplift raised the peneplain, on which were exposed sediments ranging from Archaeozoic to Upper Cretaceous. Some old streams, such as the Finke, were entrenched. Dissection of the lateritized old land surface has continued with minor uplifts, such as have caused the erosion of some Tertiary river valley fillings. The even profile of the Central Australian quartzite ranges is probably the last evidence of a period of peneplanation which preceded the post-Mesozoic uplift.

9. ECONOMIC GEOLOGY

In considering the minerals of economic importance that are found in the Alice Springs - Petermann Range area, reference is made only to the aims set for, and the results achieved by, the present expedition. The party set out to re-discover Lasseter's Reef, and returned to Alice Springs without having found any traces of gold or of any other economic mineral.

The rocks that were examined have been described above as being of Proterozoic and Archaeozoic age. The Proterozoic quartzites and schists that crop out in the Petermann and Rawlinson Ranges have been correlated with the rocks of the

Heavitree Range and the western MacDonnell Ranges south and west of Alice Springs. No gold mineralization has been discovered in the quartzites of the western MacDonnell Ranges.

The gneisses and schists south of the Petermann and Rawlinson Ranges were classed as Archaeozoic. Rocks of the Arunta Complex (Archaeozoic), and, for that matter, the majority of crystalline Archaeozoic rocks in the Northern Territory have been regarded as unfavourable for gold mineralization, as mineralization in them has been mainly of the pegmatite type, for example, in the Harts Ranges.

The country-rock in the Arltunga and White Ranges Goldfields is a quartzite which Madigan (1932) considered to be of early Proterozoic age; Voisey termed it Archaeozoic. Judging from a preliminary examination of air photos, the writer considers that it is not conformable with the crystalline schists and gneisses; on the other hand, it seems to be older than the Heavitree Quartzite. Irrespective of its exact age, the equivalent of the White Range Quartzite appears to be absent from the post-Archaeozoic succession south of Alice Springs and from the Petermann Range area.

The Tanami, the Granites and the Tennant Creek Gold Mining Fields, as well as the Hatches Creek Wolfram Mining Field, are all in rocks of supposedly Proterozoic age, but no correlation between them and any formation in the Petermann-Rawlinson Range area appears feasible.

In the course of the present expedition the only two exploratory traverses that were carried out passed over quartzites and schists of, probably, the same age as the Heavitree Range rocks. No large quartz reefs were seen, and mineralization was apparently restricted to quartz stringers and some small blows of buck quartz. No outcrops of granite, intrusive into the Proterozoic, were discovered. The small area of Archaeozoic rocks that was seen did not appear to be promising; quartz mineralization in these rocks was more marked than in the overlying quartzites and one member of the party claimed that he had obtained a "colour" of gold from a quartz vein in that area.

To sum up, no evidence of any gold mineralization or of granite intrusion was found in the course of the expedition, and the rocks traversed appear to be similar to formations that have been found to be unfavourable for mineralization in other parts of the Northern Territory.

Canberra. 15th February, 1952.

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EXPLANATION OF PHOTOGRAPHIC PLATES

Plate 3

Fig. 1. - South scarp of Petermann Range east of Livingstone Pass, showing quartzite cap and underlying schist with interbedded quartzite.

Fig. 2. - Even profile of Quartzite-capped ridge west of Irving River Crossing. Scarp faces south. Note similarity to Heavitree Range south of Alice Springs.

Fig. 3. - Permanent rock hole discovered on north side of Amphitheatre Range. Rock is Proterozoic quartzite.

Plate 4

Fig. 1. - North-east face of Ayers Rock. Vertical markings are joints; horizontal striations represent bedding.

Fig. 2. - Small overthrust fault in Proterozoic quartzite on west side of Livingstone Pass.

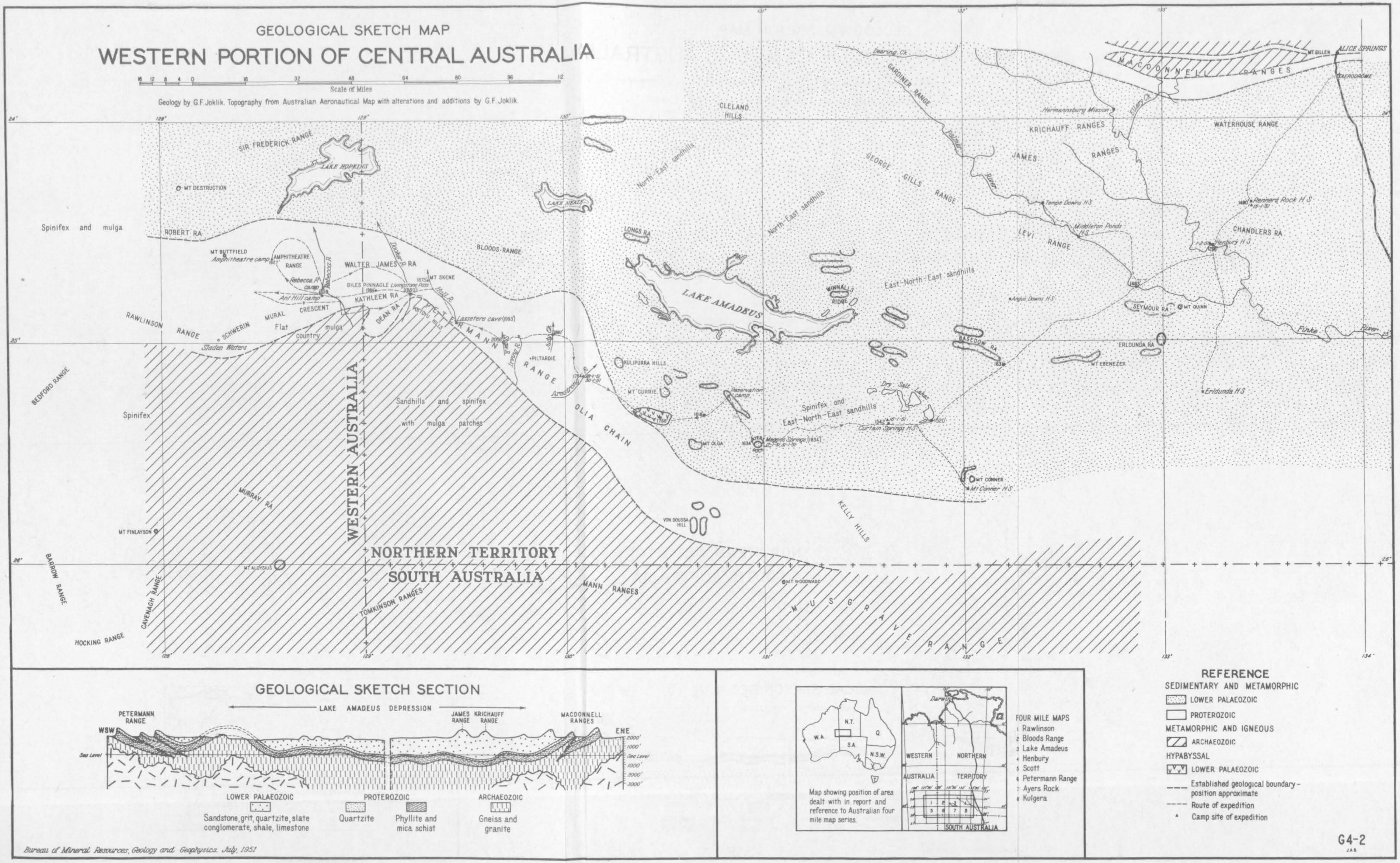
Fig. 3. - Re-entrant in south-west face of Ayers Rock, looking north. Note steep dip of beds.

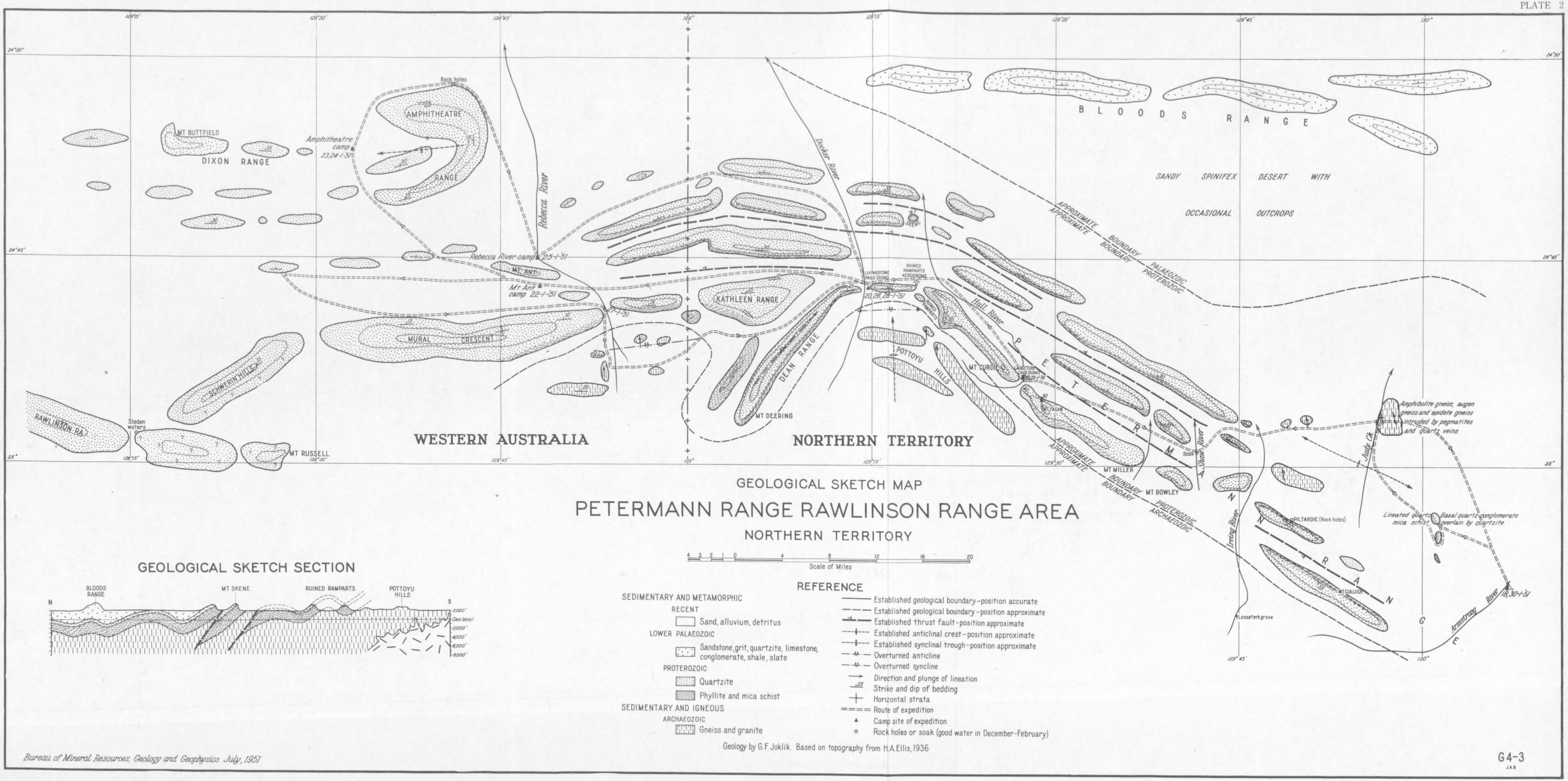
Plate 5

Fig. 1. - Angular unconformity between Archaeozoic quartz-mica schist and Proterozoic quartz conglomerate, five miles west-north-west of Armstrong River Crossing.

Fig. 2. - A Pitjentara Native.

Fig. 3. - Outcrop of quartzo-felspathic garnet-biotite-epidote gneiss one mile east of Judy River Crossing. Looking north parallel to lineation.


GEOLOGICAL SKETCH MAP
WESTERN PORTION OF CENTRAL AUSTRALIA
Scale of Miles
Geology by G.F. Joklik. Topography from Australian Aeronautical Map with alterations and additions by G.F. Joklik.
SIR FREDERICK RANGE
LAKE HOPKINS
MT DESTRUCTION
LAKE NEALE
CLELAND HILLS
North-East sandhills
GARDINER RANGE
MACDONNELL RANGES
ALICE SPRINGS
MT GILLEN
Hermannsburg Mission
KRICHAUFF RANGES
JAMES RANGES
WATERHOUSE RANGE
GEORGE GILLS RANGE
Palmer River
Tempe Downs H.S.
Middleton Ponds H.S.
LEVI RANGE
Renners Rock H.S.
CHANDLERS RA
Henbury H.S.
Spinifex and mulga
ROBERT RA
BLOODS RANGE
LONGS RA
MT BUTTFIELD
Amphitheatre camp
AMPHITHEATRE RANGE
WALTER JAMES RA
MT SKENE
GILES PINNACLE
Livingstone Pass
KATHLEEN RA
Rebecca R.
Ant Hill camp
CRESCENT
DEAN RA
Hull R.
Docker R.
LAKE AMADEUS
WINNALLS RIDGE
East-North-East sandhills
Angas Downs H.S.
SEYMOUR RA
MT QUINN
Finke River
RAWLINSON RANGE
SCHWERIN MURAL
Flat country
mulga
Sladen Waters
Lasseters cave
PETERMANN RANGE
PILTARDIE
Armstrong R.
BASEDOW RA
ERLDUNDA RA
MT EBENEZER
Erldunda H.S.
BEDFORD RANGE
Spinifex
Sandhills and spinifex with mulga patches
KULIPURRA HILLS
MT CURRIE
Reservation camp
Dry Salt Lakes
Spinifex and East-North-East sandhills
Curtain Springs H.S.
OLIA CHAIN
MT OLGA
Maggie Springs
MT CONNER
Mt Conner H.S.
WESTERN AUSTRALIA
MURRAY RA
MT FINLAYSON
VON DOUSSA HILL
KELLY HILLS
NORTHERN TERRITORY
SOUTH AUSTRALIA
MT ALOYSIUS
BARROW RANGE
CAVENAGH RANGE
TOMKINSON RANGES
MANN RANGES
MT WOODWARD
MUSGRAVE RANGE
HOCKING RANGE
GEOLOGICAL SKETCH SECTION
LAKE AMADEUS DEPRESSION
PETERMANN RANGE
JAMES RANGE
KRICHAUFF RANGE
MACDONNELL RANGES
WSW
ENE
Sea Level
LOWER PALAEOZOIC
Sandstone, grit, quartzite, slate conglomerate, shale, limestone
PROTEROZOIC
Quartzite
Phyllite and mica schist
ARCHAEOZOIC
Gneiss and granite
Map showing position of area dealt with in report and reference to Australian four mile map series.
FOUR MILE MAPS
1 Rawlinson
2 Bloods Range
3 Lake Amadeus
4 Henbury
5 Scott
6 Petermann Range
7 Ayers Rock
8 Kulgera
REFERENCE
SEDIMENTARY AND METAMORPHIC
LOWER PALAEOZOIC
PROTEROZOIC
METAMORPHIC AND IGNEOUS
ARCHAEOZOIC
HYPABYSSAL
LOWER PALAEOZOIC
Established geological boundary - position approximate
Route of expedition
Camp site of expedition
Bureau of Mineral Resources, Geology and Geophysics. July, 1951
G4-2


BLOODS RANGE
SANDY SPINIFEX DESERT WITH OCCASIONAL OUTCROPS
Rock holes
AMPHITHEATRE
RANGE
Amphitheatre camp 23,24-I-'51
MT BUTTFIELD
DIXON RANGE
Rebecca River
Rebecca River camp 25-I-'51
MT ANT
Mt Ant camp 22-I-'51
Decker River
KATHLEEN RANGE
MURAL CRESCENT
SCHWERIN HILLS
RAWLINSON RA
Sladen waters
MT RUSSELL
DEAN RANGE
MT DEERING
LIVINGSTONE PASS (SOAK)
20,26,28-I-'51
RUINED RAMPARTS AERODROME
MT SKENE
POTTOYU HILLS
MT CURDIE
Hull River
P E T E R M A N N R A N G E
MT FAGAN
MT MILLER
MT BOWLEY
Shaw River
Irving River
PILTARDIE (Rock holes)
MT CULLOCH
Armstrong River
18,30-I-'51
Judy Ck
Lasseter's grove
APPROXIMATE BOUNDARY PALAEOZOIC PROTEROZOIC
APPROXIMATE BOUNDARY PROTEROZOIC ARCHAEOZOIC
Amphibolite gneiss, augen gneiss and epidote gneiss intruded by pegmatites and quartz veins
Lineated quartz mica schist
Basal quartz conglomerate overlain by quartzite
WESTERN AUSTRALIA
NORTHERN TERRITORY
GEOLOGICAL SKETCH MAP
PETERMANN RANGE RAWLINSON RANGE AREA
NORTHERN TERRITORY
Scale of Miles
GEOLOGICAL SKETCH SECTION
BLOODS RANGE
MT SKENE
RUINED RAMPARTS
POTTOYU HILLS
N
S
2,000'
Sea level
2,000'
4,000'
6,000'
8,000'
REFERENCE
SEDIMENTARY AND METAMORPHIC
RECENT
Sand, alluvium, detritus
LOWER PALAEOZOIC
Sandstone, grit, quartzite, limestone, conglomerate, shale, slate
PROTEROZOIC
Quartzite
Phyllite and mica schist
SEDIMENTARY AND IGNEOUS
ARCHAEOZOIC
Gneiss and granite
Established geological boundary-position accurate
Established geological boundary-position approximate
Established thrust fault-position approximate
Established anticlinal crest-position approximate
Established synclinal trough-position approximate
Overturned anticline
Overturned syncline
Direction and plunge of lineation
Strike and dip of bedding
Horizontal strata
Route of expedition
Camp site of expedition
Rock holes or soak (good water in December-February)
Geology by G.F. Joklik. Based on topography from H.A.Ellis, 1936
Bureau of Mineral Resources, Geology and Geophysics July, 1951
G4-3

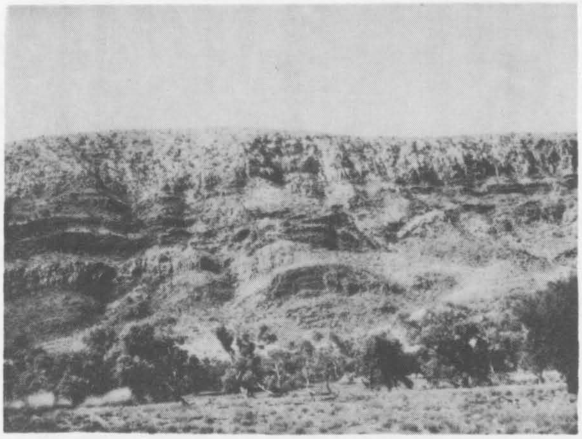


Fig. 1

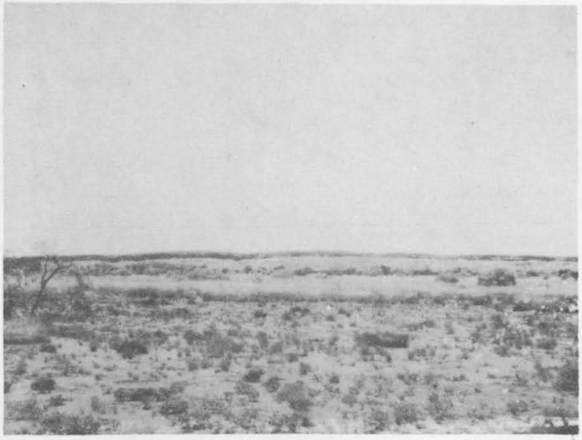


Fig. 2

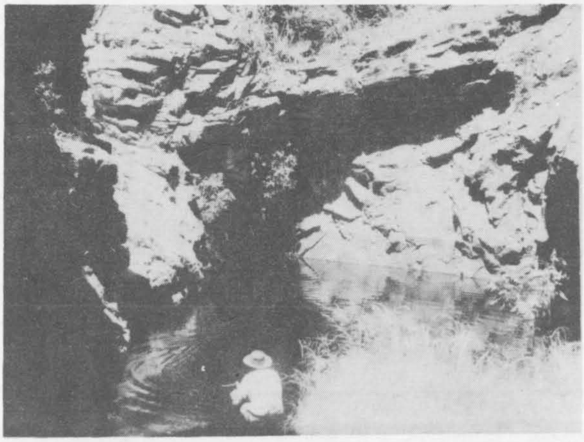
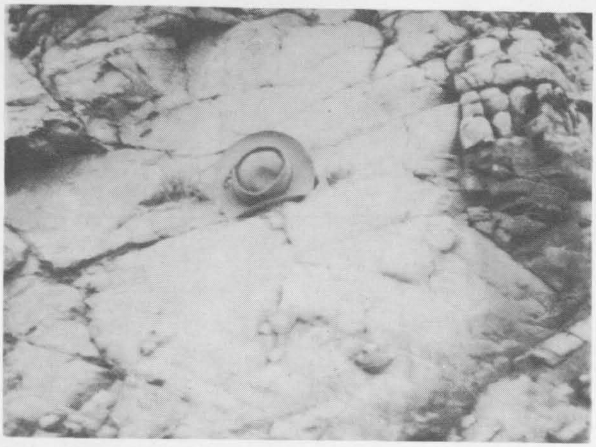


Fig. 3

PLATE 4

Fig. 1

Fig. 2



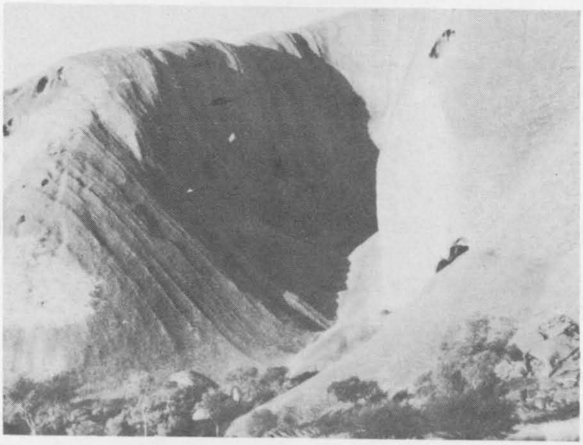


Fig. 3

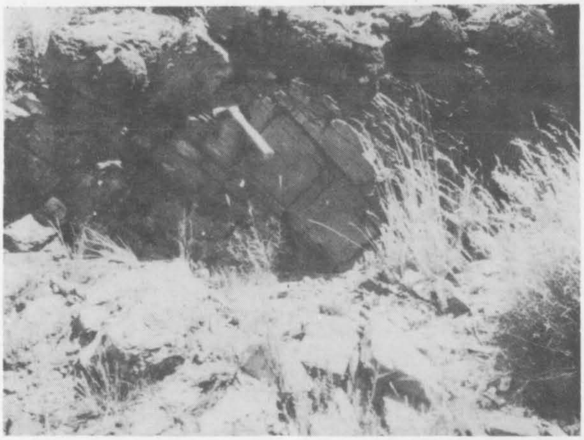


Fig. 1

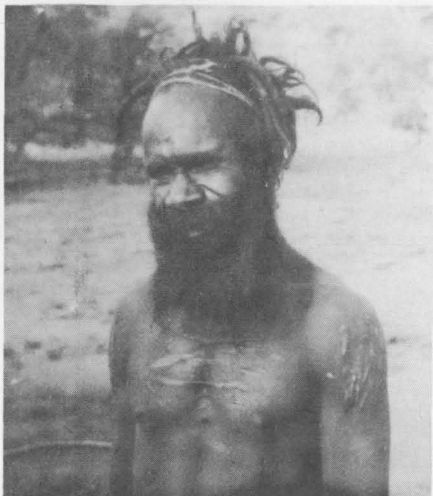


Fig. 2

Fig. 3